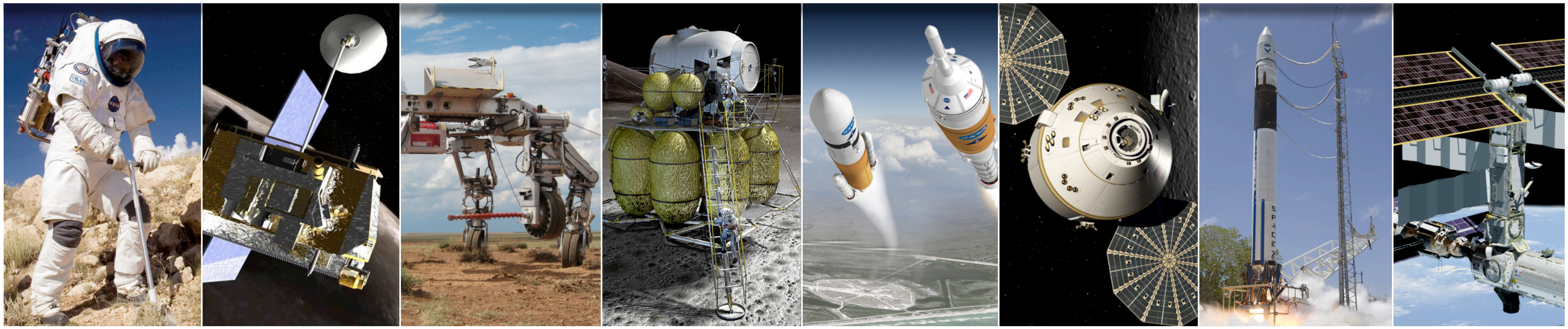
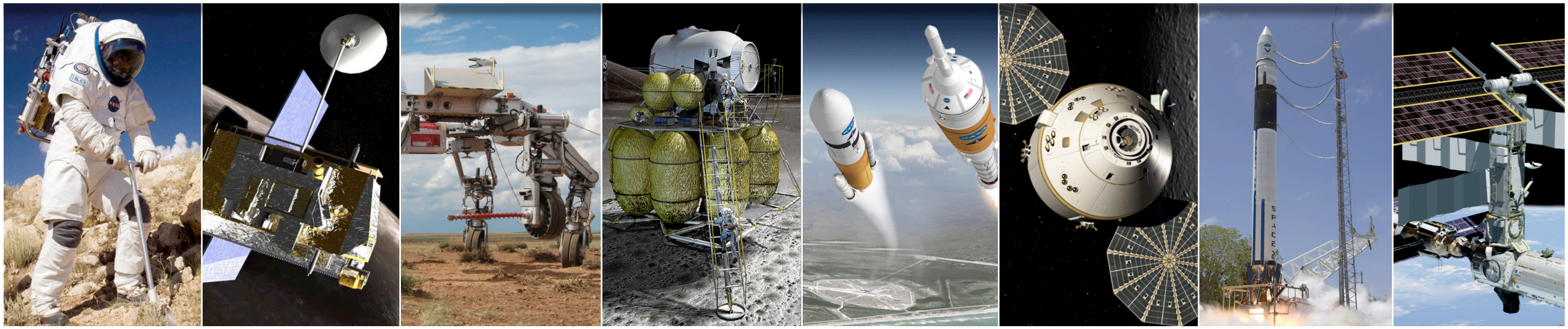


# Exploration Systems Mission Directorate Exploration and Science: An Update

Michael J. Wargo, Sc.D.
Chief Lunar Scientist for Exploration Systems
Exploration Systems Mission Directorate



# Exploration Systems Mission Directorate: Exploration and Science: An Update

Michael J. Wargo, Sc.D.
Utility Infielder
Exploration Systems Mission Directorate

# Outline - Exploration in Support of Science

- **What's new in the Exploration Systems Mission Directorate and the Advanced Capabilities Division**
  - Where are we now?
    - Is there still time to influence how we'll do things on the Moon?
  - Lunar Precursor Robotic Program (LPRP)
    - Transition to Science - Lunar Reconnaissance Orbiter (LRO) Extended Mission is dedicated to science
    - Lunar Mapping and Modeling Project
      - Lunar Geodesy and Cartography Working Group
  - Exploration Technology Development Program
    - Mobility for surface operations
    - Moses Lake analog tests
- **Optimizing Science and Exploration Working Group (OSEWG): Status and Recent Activities**
  - Working groups and teams
  - Joint OSEWG/LPRP targeting / site characterization workshop
- **Joint SMD/ESMD Research**
  - Lunar Advanced Science and Exploration Research (LASER)
  - NASA Lunar Science Institute Cooperative Agreement Notice (NLSI CAN)

# Architecture Driven By A Strategy
# Where We Have Been and Next Steps

Global Exploration Strategy Development – Themes and Objectives

*Architecture Assessment (LAT1) Dec 06 – Outpost first at one of the Poles, elements critical to US*

***Detailed Design Concepts (LAT2) Aug 07 – Operations concepts, technology needs, element requirements***

***Lunar Capabilities Concept Review June 08 – Refinement of concepts in support of the transportation system***

***Surface system concepts but no final designs***

***Lunar surface systems concept review - 2010***

***Lunar transportation system SRR***

***Lunar surface systems SRR - 2012***

***Lunar Surface System Element SRRs***

*Time*

# Lunar Precursor Robotic Program - Strategic Status

- NASA has decided to shift emphasis on lunar robotic missions from ESMD to SMD after the LRO and LCROSS missions
  - New Program started (CY ‘07) within SMD called Lunar Science Program (LSP)
  - Due to budget limitations and lack of hard requirements, no new missions will be planned for ESMD
- LPRP will disband as a Program sometime after LRO/LCROSS (Lunar Crater Observation and Sensing Satellite) launch. However, there are still a number of activities that will be carried forward within ESMD
  - LRO ESMD mission
  - Lunar Mapping and Modeling Project
  - ESMD supported LASER grants in applied science
  - Program (and LRO project) EPO
  - Instrument activity in some form

# Part of the ESMD Mission: Advancing Capabilities (Many of Which Enable Science)

- Explore the solar system and beyond
- Extend human presence across the solar system, starting with a human return to the moon by the year 2020, in preparation for human exploration of Mars and other destinations
- Develop the innovative technologies, knowledge, and infrastructures both to explore and to support decisions about future destinations for human exploration
- Promote international and commercial exploration participation to further U.S. scientific, security, and economic interests

# The EVA System Design Approach

- A single spacesuit system with two configurations which share many components
- Common, evolvable infrastructure
- Minimum set of hardware to meet all mission phase requirements
- Modular, reconfigurable, component-based open architecture

Launch and Entry

In-space Contingency

Lunar Surface

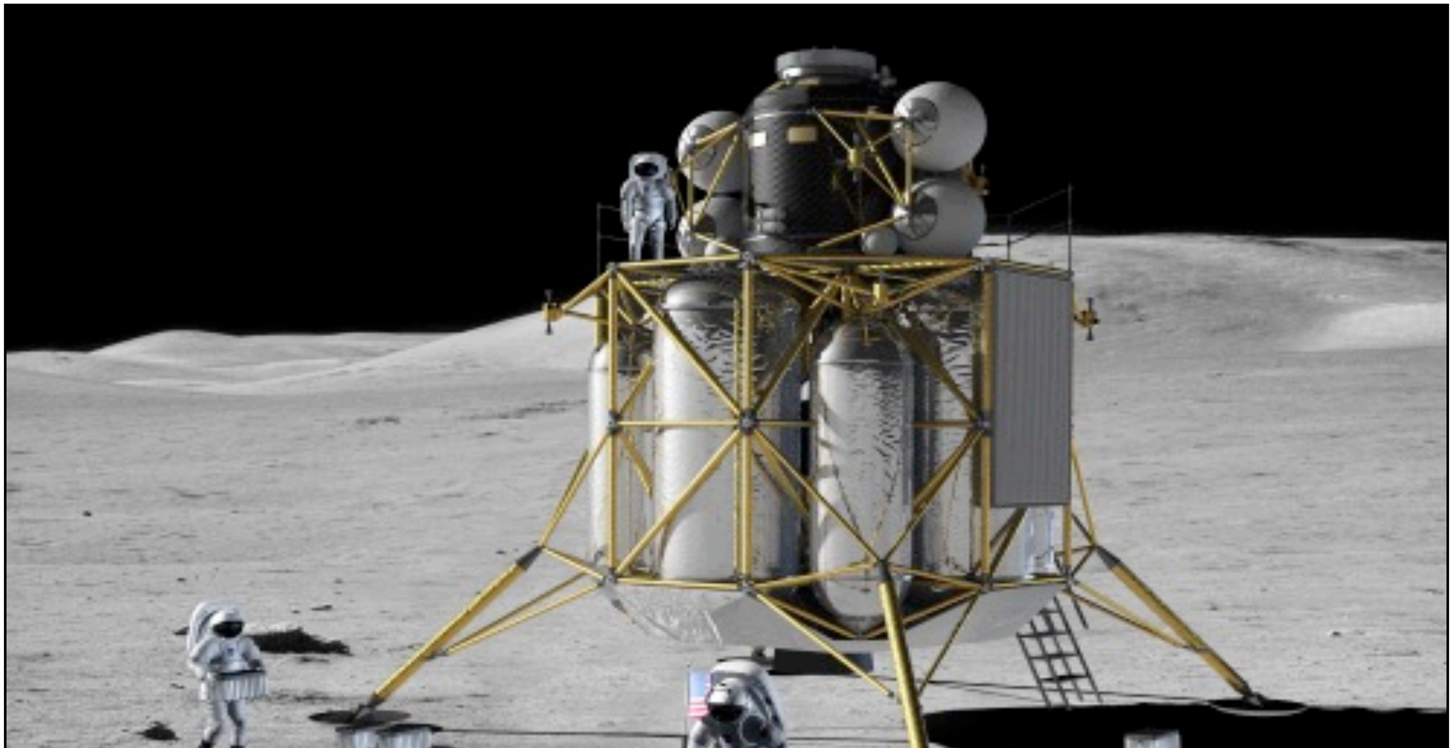
# Technology Development for Ares Launch Vehicles

**Structures & Materials:** Developing friction stir welding and spin forming manufacturing processes for Ares I Upper Stage propellant tanks.

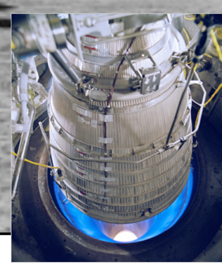
**Structures & Materials:** Developing lightweight composite structures for Ares V payload fairing.

**Integrated Systems Health Monitoring:** Developing health monitoring system for Solid Rocket Motor.

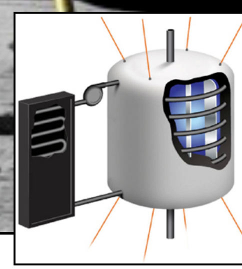
# Technology Development for Altair Lunar Lander



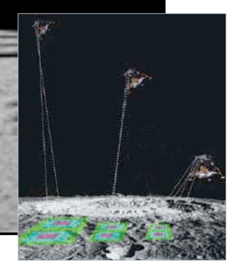
**Propulsion & Cryogenics:** Prototype LOX-Methane engine for ascent stage



**Propulsion & Cryogenics:** Prototype deep throttling RL-10 engine for descent stage

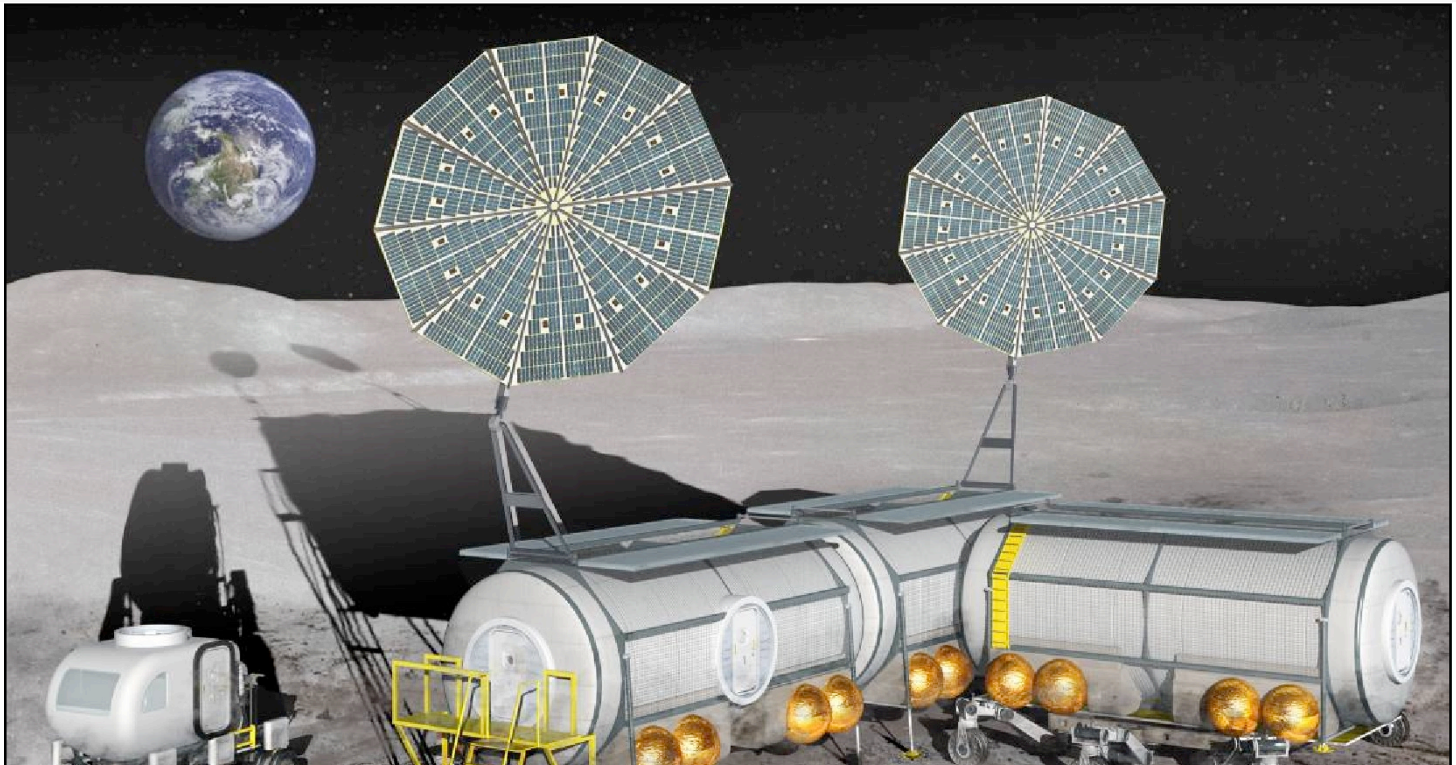


**Propulsion & Cryogenics:** Zero boil off cryogenic propellant storage for long duration missions

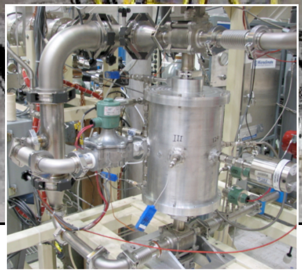


**Autonomous Landing:** Guidance algorithms & lidar sensors to enable precision landing and hazard avoidance.

# Technology Development for the Lunar Outpost

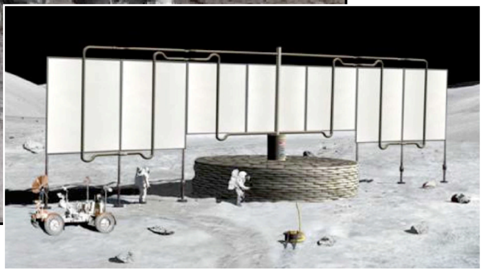


**Structures & Materials:** Inflatable habitats to reduce launch volume



**Life Support:** Closed-loop life support systems to reduce consumables

**Energy Storage:** Regenerative fuel cells to store energy during the lunar night



**Power:** Affordable fission surface power systems

# Advanced Robotics for Lunar Exploration To Be Demonstrated at Moses Lake

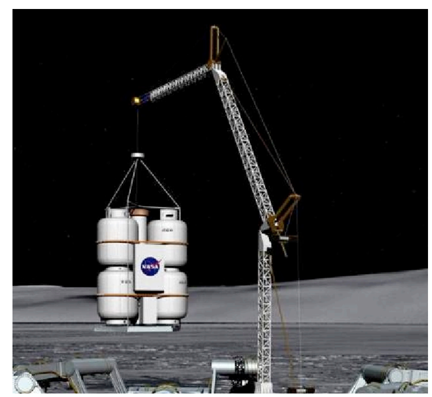
"Chariot" unpressurized rover will be used to transport crew and large payloads for lunar outpost assembly.

Two ATHLETE rovers will be used to demonstrate the transport and docking of lunar habitat mockups.

"Scarab" rover developed by Carnegie Mellon University will be used to demonstrate prospecting for lunar resources.

K10 rover will be used to survey and map terrain at potential sites for the lunar outpost

Remotely controlled front end loader developed by Caterpillar will be used for site preparation



Payload handling crane will be used to demonstrate off-loading small payloads from Lunar Lander.

# Moses Lake Analogue Activities

- Moses Lake human robotic system 2 week testing completed on June 13th.
- 7 NASA Centers (ARC, GSFC, LaRC, JPL, JSC, GRC, KSC) and 1 university (Carnegie Mellon) collaborated on the test.
- Concepts on outpost element deployment and human/robotic interaction developed by CxAT Lunar and LAT were demonstrated.
- High fidelity science operations were demonstrated by the real time interaction of the EVA team and the mission ops/science team located remotely. EVA team used vintage Apollo tools for sample collection.
- Testing included the **Chariot lunar truck**, **2 athlete rovers** with habitat shells attached, **2 K-10 rovers**, a **prototype Lunar crane**, and engineers suited both with high fidelity prototype suits and low fidelity lighter weight suits (which looked just like the Mark 3 prototype suit), local and remote commanding of the robots, and deployment of a command/information network to provide commanding from the base camp to a depression (simulated crater) a kilometer away.
- Excellent interaction with the local community and schools (included a visit by Miss Moses Lake 2008). Interaction yielded recommendation for alternative tire tread pattern for Chariot which was implemented near real time.

# *Optimizing* Science and Exploration Working Group

## Updates to the Charter

- Co-Chairs: Marguerite Broadwell, ESMD; Gordon Johnston & Kelly Snook, SMD
- **Includes *all* science** (Added Materials, Physical and Life Sciences)
- Not just Outpost, includes sortie, orbiters…
- Liaison to LEAG for SMD and ESMD
- Formulated a Science Objectives Team
- Engage the science and exploration communities (includes LEAG, CAPTEM, MEPAG, and other fora)
  - Website being developed for access by the external communities

## How We Work

- OSEWG leadership reports to ESMD and SMD Deputy AAs bi-monthly
- Working groups and teams focused on:
  - **Analogue Missions** - Kelly Snook, Doug Craig
  - **Surface Science Scenarios** - Laurie Leshin, Doug Craig
  - **Lunar Data Integration** - Michael Wargo, Gordon Johnston
  - **Science Objectives** - Gordon Johnston, Marguerite Broadwell
- Cognizant of related activities (e.g., NASA Partnership Integration Committee, SMD Lunar Program, LEAG, ILEWG)

# Joint Science *and* Exploration Research

- **Lunar Advanced Science and Exploration Research (LASER) 2007**
  - 161 proposals submitted, 159 proposals reviewed
    - More than 100 proposals had greater than 40% Exploration/Science synergy
  - Exploration supported the selection and funding of 15 proposals
    - 8 proposals are **jointly funded** with SMD
    - Proposals were assessed by ESMD for alignment with current research priorities
- **NASA Lunar Science Institute Cooperative Agreement Notice (NLSI CAN)**
  - Almost 60 Notices of Intent received
  - More than half have Exploration relevance

# Backup Charts

National Aeronautics and Space Administration

# Surface Science Scenarios

**Laurie Leshin**
**Doug Craig**

# OSEWG Surface Science Scenario Working Group

## Objectives:

- Construct Campaign-level (multi-mission) Science Scenarios, Lunar Surface Science Scenarios for single missions, and Design Reference Science Investigations that highlight scientific goals and objectives for examination by the appropriate teams for planning the lunar surface missions, campaigns, and architectures
- Use analysis of selected surface scenarios to drive concepts of operations and requirements for the Constellation program and appropriate projects (e.g., Altair, EVA, and Surface Systems Projects) or in SMD Programs (e.g., LASER, LSSO, MMAMA, ASTEP) or missions (e.g., LADEE, ILN), and present requirements for incorporation into the appropriate requirements documents
- Use analysis of selected surface scenarios to drive planning for analog studies
- Engage the science and exploration communities in discussion of surface scenarios

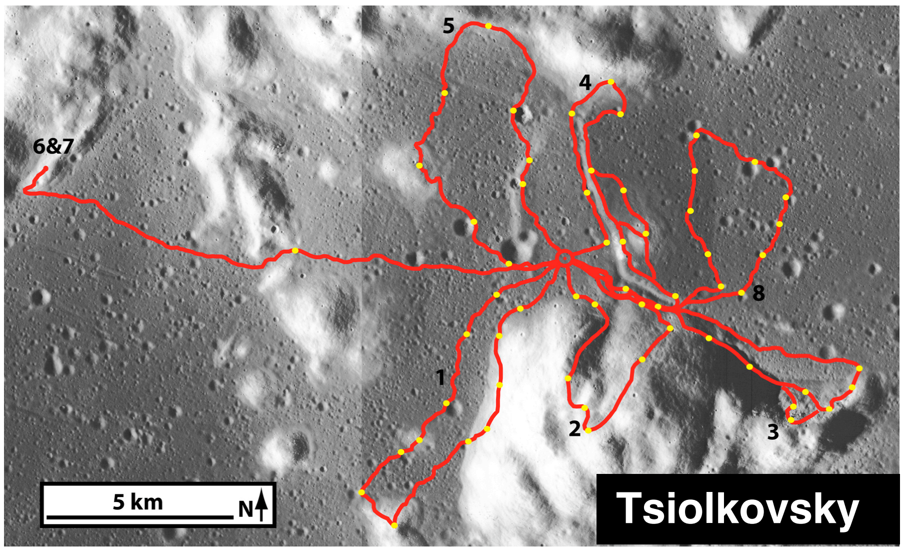
# OSEWG Surface Science Scenario Working Group

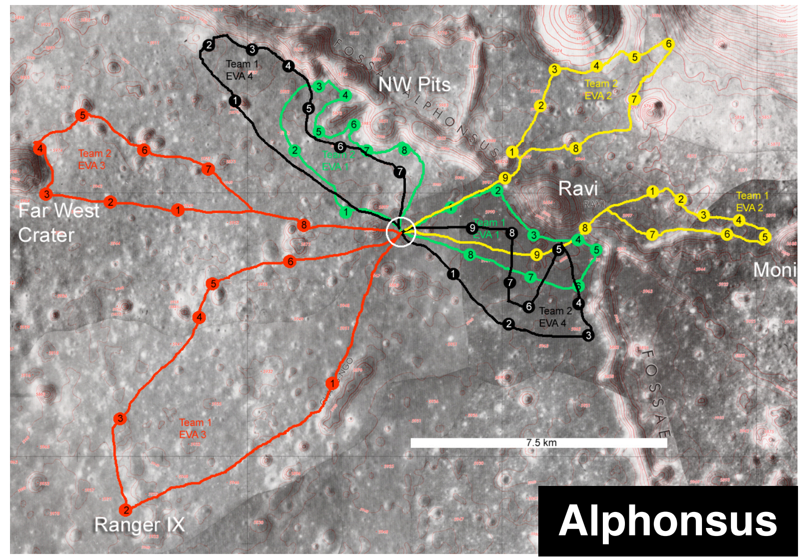
## Current Activities:

- Developing surface scenarios for individual lunar missions at different types of lunar sites:
  - Phase 1: Exploration on the order of 7 days and 10 km radial distance from a landing site.
  - Phase 2: Exploration on the order of 45 days and 100 km radial distance.
  - Phase 3: Exploration on the order of 180 days and 1000 km distance.
- Developing overarching approach for metrics for evaluating likely scientific return from lunar missions and campaigns as measured against NAC lunar science objectives from Tempe Workshop as well as NRC SCEM Report Objectives

# OSEWG SSSWG Conducted Phase 1 Workshop: Planning Sorties at Tsiolkovsky and Alphonsus

- Two groups of four scientists were tasked with Tsiolkovsky or Alphonsus craters and asked to design an exploration plan driven by scientific rationale. The exercise assumed a total of eight, two-man EVAs of eight hours, including the use of two unpressurized rovers




- Results will be reported at NLSI Lunar Science Conference in July and folded into approach for longer surface stay scenario planning and metric development

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# Analogue Missions


**Kelly Snook**
**Doug Craig**

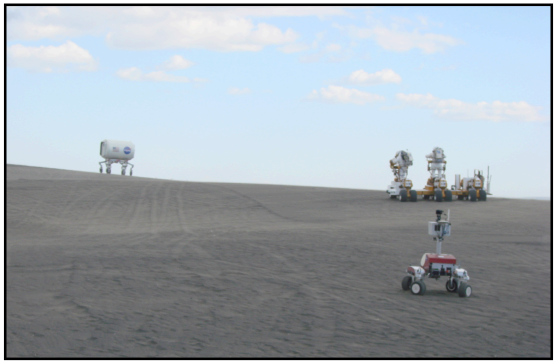
# ESMD Integrated Field Test, Moses Lake Washington, June 2008

## A Record Setting Field Test:

- 7 Centers, 2 Directorates + 1 Univ. in the field
- Ground supervision of 3 robots (including incorporation of time delays)
- 8 Robotic systems at site
- >200 Hrs of experimentation
- >50 Kilometers driven
- >5km of night ops

- Most data collected (timelines, GPS…)
- Most alignment to architecture
- Most public participating at site
- Most integration of Lunar Science

- Lessons learned to be folded into HMP and October analog mission and field test activities



# Moses Lake Field Testing of Science Operations

Tasks:

- **Identify visualization and science operation methods using the Apollo site survey baseline procedures and existing technologies for a science backroom Science Backroom:**
- **Use robotic rover to "high grade" a site: identify, triage, and prioritize science targets for follow-up human activity**
- **Obtain performance metrics of the ground control architecture's ability to effectively support science backroom operations**
- **Timeline baseline surface operations (i.e., sampling, tagging, etc.)**

Results:

- **Current technologies and operational practices do not support real time science operations directed by the backroom. To perform a successful science operation, the science team has to coordinate and develop good pre-test science activity task planning.**
- **Exercises of this kind benefit from having at least one trained geologist among the crew to more fully exploit the significance of a site's geologic history and potential. Additionally, without a trained geologist among the crew, the back room is not exercised properly.**
- **It is difficult for a field observer to keep up with the extensive imagery and other information being analyzed and interpreted by many individuals manning the science back room.**

Forward Work:

- **Complete collection, synthesis, and documentation of lessons-learned (in preparation for Oct field tests).**
- **Ensure site characterization data is available early enough to perform proper pre-mission planning (i.e., identifying sites of interest, laying out traverse paths, etc.).**
- **Identify exploration teams (including 2-3 geologists) that will be used over the next several years to validate operational concepts**
- **Incorporate the current visualization tools in the science backroom operations.**

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# Lunar Data Integration

**Michael Wargo**
**Gordon Johnston**

# Lunar Data Integration Activities & Plans

## Scientific Input to Landing Sites and Operational Decisions:

- The Lunar Reconnaissance Orbiter Camera (LROC) project of LRO has developed a target planning system to solicit, prioritize, and plan on-orbit operations to acquire exploration and science targets.
- Science targets will be solicited from the science community by the LROC project coordinated through the LRO project science office. A workshop will be planned to consolidate and prioritize the targets.
- The LPRP Lunar Mapping and Modeling Project (LMMP) is working with Constellation to identify required characteristics of exploration targets, i.e. geometry, landing hazard assessment, slopes, lighting, etc.
  - This information will inform the development of the LMMP and be used as screening criteria for the selection and prioritization of potential landing sites.
- An OSEWG/LMMP sponsored LRO/LROC targeting workshop with Constellation will be held in October to integrate science and exploration targeting needs.

# Lunar Data Integration Activities & Plans

## Integration of Orbital Data Sets:

- The LPRP Lunar Mapping and Modeling Project is tasked to ensure that LRO data sets will be geodetically controlled and co-registered based on a control network derived from the LRO/LOLA data.
  - Exploration-relevant data will be geodetically controlled and co-registered.
  - SMD will geodetically control and co-register science data.
  - All LRO data will be available in the Planetary Data System

- LPRP has chartered the Lunar Geodesy and Cartography Working Group (modeled after the Mars Geodesy/Cartography Working Group)
  - Chartered in late 2007 for coordination of lunar cartographic standards and constants
  - Chaired by Brent Archinal (USGS)
  - Membership from ESMD, SMD, external, international space agencies and lunar missions
  - Will report results and findings to the IAU/IAG Working Group on Cartographic Coordinates and Rotational Elements

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# Science Objectives

## Gordon Johnston

# OSEWG Science Objectives Team (SOT)

- Team: **Interdisciplinary, NASA civil servant scientists**
- Objectives:
  - Conduct systematic science reviews of existing Exploration Architecture Requirements Document (EARD) and Constellation Architecture Requirements Document (CARD)
  - Review output of other OSEWG working groups (Analogues and Surface Science Scenarios) to ensure consistency with EARD and CARD
  - Begin generating and defining new science objectives not yet identified.
  - Facilitate definition of science objectives in terms of threshold and objectives to facilitate architecture trade assessments
  - Assess urgency of resolving uncertainty of science objectives based on when architecture development team needs the information.
  - Propose recommended approach(es) to OSEWG leadership for prioritizing and further defining science objectives.

# OSEWG Science Objective Team (SOT)

## Current Activity:

- Interdisciplinary science review of EARD and CARD for impact on science, identifying requirements as one of the following:
  - requirement is conducive and adequate for science
  - requirement could require additional study or trades for science
  - requirement is inadequate or will prevent science

- OSEWG will use SOT results to:
  - Submit request for assessment by Constellation
  - Propose a change to current EARD and/or CARD
  - Commission external studies or workshops to address yellow and red flagged issues (e.g. LEAG, MEPAG, CAPTEM, NRC, etc.)